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Development and use of a hydrologic and water-quality model of the Delaware Inland Bays Watershed

Progress Report July 1–December 31, 2000

Water Resources Division
MD-DE-DC District Office
8987 Yellow Brick Road
Baltimore, MD 21237

Phone: 410-238-4200
Fax: 410-238-4210
Website: http://md.water.usgs.gov

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Personnel

Angelica Gutiérrez-Magness, Hydrologist (Project Chief, effective 2/18/01)
Jeff Raffensperger, Hydrologist (Chief, Watershed Studies Section)
Sarah Kelley, Geographer
Gary Fisher, Surface-Water Specialist

Project Description

Problem

The Delaware Inland Bays have experienced significant environmental degradation due to human activities over the past several decades. Excessive nutrients and sediment are among the most severe environmental stressors in the Inland Bays. The sources of nutrients, sediment, and other contaminants include point-source discharges from industries and wastewater-treatment plants, runoff and infiltration to ground water from agricultural fields and poultry operations, septic-system effluent, and atmospheric deposition.

In order to determine how best to approach restoration of the Inland Bays, it is necessary to understand the relative distribution and contribution of each of the potential sources of nutrients, sediment, and other contaminants. It is also important to understand the hydrology of the Inland Bays Watershed in order to effectively restore them. Understanding the complex interrelations and interactions between hydrology and the various water-quality inputs is a prerequisite to restoration.

Objective

This project is a cooperative effort involving the Delaware Department of Natural Resources and Environmental Control (DNREC), the Delaware Geological Survey (DGS), and the U.S. Geological Survey (USGS). The objective of this project is to develop a hydrologic and water-quality model of the Delaware Inland Bays Watershed that can be used as a water-resources planning and management tool. The water-quality constituents of concern will be suspended sediment and nutrients (nitrogen and phosphorus). A well-documented model, Hydrologic Simulation Program—FORTRAN (HSPF), will be applied by the USGS to meet the objective.

The USGS role in this cooperative project is to construct, calibrate, and demonstrate the use of the hydrologic and water-quality model for the portion of the Inland Bays Watershed discharging to the Bays themselves. The following tasks are included in this role: (1) Compilation of existing hydrologic, climatological, water-quality, and ancillary data into model data sets; (2) construction and calibration of a hydrologic model; (3) construction and calibration of a water-quality model for suspended sediment, nitrogen, and phosphorus; (4) use of the model to simulate selected scenarios of the allocation of point and nonpoint sources; and (5) presentation of the model results to DNREC and DGS in the form of electronic model files, a written USGS report, and training in use of the model.

Background

The hydrologic and water-quality data needed to calibrate the model were collected during Federal Fiscal Year 1999 and the beginning of Federal Fiscal Year 2000. The USGS collected streamflow data at six stations in the Delaware Inland Bays Watershed (Fig. 1), and the University of Delaware and

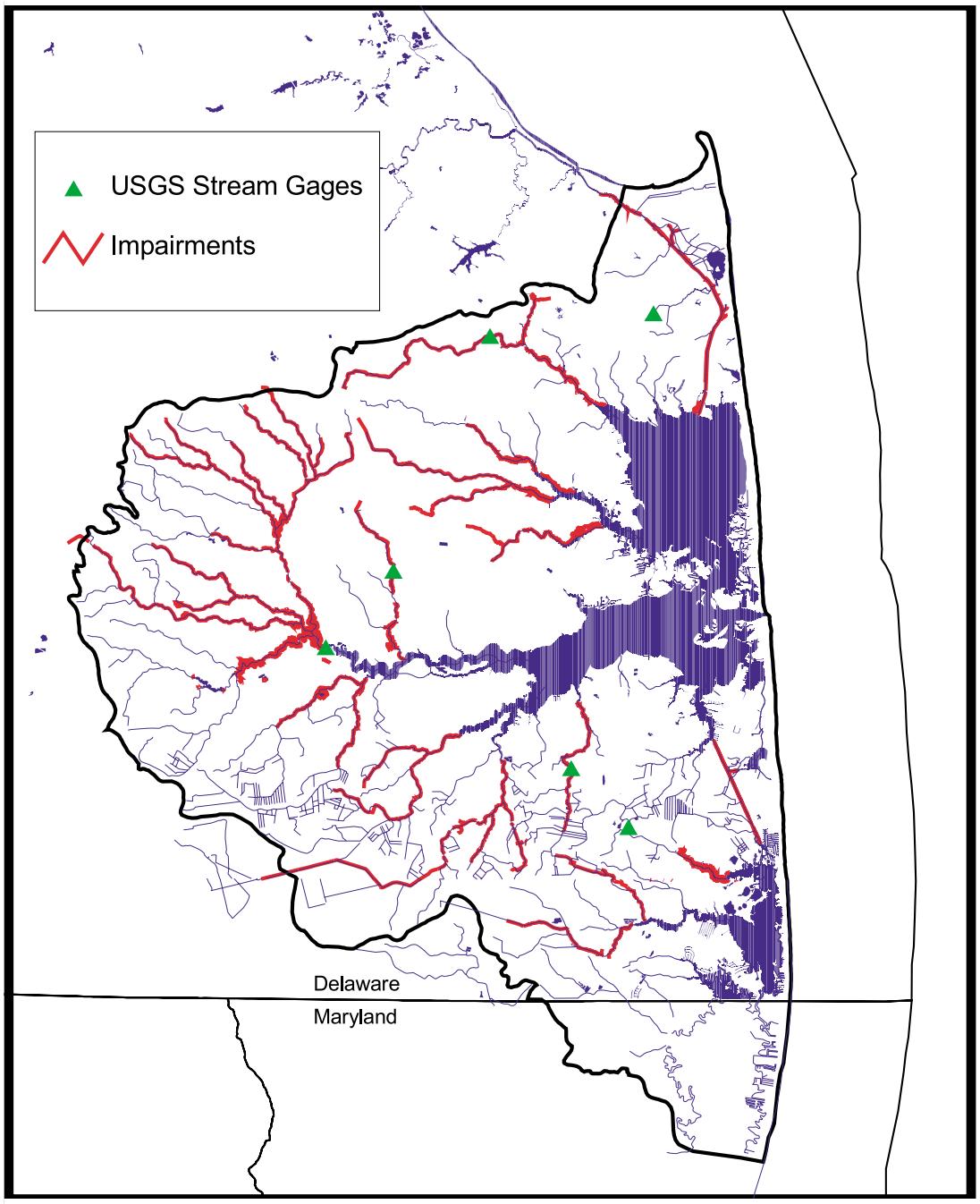

Figure 1. Delaware Inland Bays Watershed study area, impaired stream reaches, and USGS stream-gaging stations

DGS collected water-quality data at the same six stations for the same time period. All the streams for which data were collected (except Munchy Branch, 01484668) are on Delaware's 303(d) list, and all six streams also were monitored as part of Delaware's water-quality monitoring program in Federal Fiscal Years 1999 and 2000.

Responsibilities

USGS is responsible for developing the HSPF model framework and for model calibration. The framework of the model is based on Geographic-Information-System (GIS) data in ARC/INFO format previously prepared by USGS for DGS, and supplemented by DNREC and other agencies as appropriate. GIS data include land use, geology, soils, digital-elevation-model (DEM) data, drainage basins, stream network, data-collection points, and point-source discharges. The data sets will be properly attributed and include critical information such as fertilizer application rates and timing for agricultural areas and lawns. USGS will use the GIS data to build the framework of the model and produce appropriate model segmentation. USGS will provide streamflow data and assemble climatological data for model operation.

DNREC is responsible for providing existing water-quality data including suspended-sediment, nitrogen, and phosphorus concentrations for calibration points and other model nodes of interest. These data will include all the water-quality data collected by the University of Delaware and DGS during 1999 and 2000 at the six established stream stations mentioned above, as well as any other pertinent water-quality data for the Inland Bays Watershed. DNREC will also provide quantity and quality data for point-source discharges to streams in the study area, and supply or facilitate the obtaining of other data needed for the model application, including stream hydraulic characteristics and fertilizer-application data.

DGS is responsible for supplying selected data that may enhance the model application, including analysis and interpretation of results. DGS provides coordination between USGS and DNREC as appropriate.

Approach

Data compilation

Numerous data will be needed to calibrate and verify the hydrologic and water-quality model. USGS is responsible for gathering those data and compiling them in model-ready format, as well as any necessary climatological data. USGS will also compile pertinent available streamflow and water-quality data from their files. As appropriate, DNREC and DGS will supply USGS with electronic copies of their data holdings, including water-quality data from the six monitored stream stations. DNREC's contributions will include point-source data. All input data for the HSPF model will be converted to the appropriate format for the most efficient use in the model.

Hydrologic modeling

This phase of the project will be aimed at calibrating the modeled hydrologic response of the Inland Bays Watershed to measured streamflow at USGS stream-gaging stations. Calibration will be done for the six watersheds where data collection was conducted during 1999-2000. For the five stations that were newly established for this study, the entire new period of record will be used for calibration. For the station at the Millsboro Pond outlet (01484525), where a longer period of record is available, at least one year of the most recent data will be reserved for verification of the hydrologic model.

Water-quality modeling

Water-quality modeling will include simulation of concentrations and loads of suspended sediment, nitrogen, and phosphorus. Suspended sediment will be the first water-quality parameter modeled, because the sediment results will be needed for modeling of phosphorus. Suspended-sediment data that were collected at the six stations in 1999-2000 will be used to calibrate the HSPF model.

Nitrogen concentrations and loads will be modeled following calibration for suspended sediment. DNREC will supply or facilitate obtaining of data on fertilizer application rates and timing and other sources of nitrogen, such as point sources, septic systems, disposal of poultry wastes, and atmospheric

deposition. Measured nitrogen concentrations at the six stream-gaging stations will be used to calibrate the HSPF model.

Phosphorus concentrations and loads will be modeled following calibration for suspended sediment and nitrogen. Phosphorus is transported mainly with sediment, so completion of the phosphorus component of the model cannot be accomplished prior to development of the sediment component. DNREC will supply or facilitate obtaining of data on fertilizer application rates and timing of other sources of phosphorus, including point sources, septic systems, and disposal of poultry wastes. Measured phosphorus concentrations at the six stream-gaging stations will be used to calibrate the HSPF model.

Because only about one year of water-quality data collection was conducted at the six stations for this study, verification of HSPF for water-quality simulations will not be possible if all data are used for model calibration. A potential approach for verifying the model for water quality is to reserve the data from one of the six monitored watersheds for verification. In that case, no calibration would be done for that watershed and model parameters would be based on the modeling of the other five watersheds.

Scenario Generation

Following model calibration and verification (to be completed by December 31, 2001), a scenario generator, GENSCN, will be added to the HSPF model to meet the specific needs of DNREC and DGS and other agencies involved in the management of the Delaware Inland Bays Watershed. Desired scenarios of various allocations of sediment and nutrient loads will be provided to USGS by DNREC and DGS by December 31, 2001, for simulation in the calibrated model. During the scenario-generation stage (January 1, 2002 through June 30, 2002), the USGS will work closely with DNREC and DGS staff, as appropriate, to provide them training in the application of the model.

Progress

Data Acquisition

The first six months of effort focused primarily on acquiring appropriate data necessary to begin compilation of databases and GIS data layers necessary for HSPF model development. Table 1 lists the basic data necessary, as well as the source of that data. Data types listed in bold have been acquired as of December 31, 2000. Of critical initial interest are databases and spatial data relevant to hydrologic model calibration, beginning with watershed model segmentation. This includes DEMs, hydrography, drainage basin or subwatershed delineations, and the location of stream gages, water-quality stations, impaired stream segments (Fig. 1), and the locations of municipal and industrial point sources. USGS has obtained most of the information required, but inconsistencies in the point-source data need to be resolved. Also, the University of Delaware Spatial Analysis Laboratory (SPATLAB) is in the process of developing a GIS coverage of subwatersheds in Sussex County, Delaware, that should be available soon. This spatial data, in conjunction with other information listed above, will be necessary to develop initial model segmentation.

Plans for Next Six Months

1. Complete acquisition of data (items not in bold in Table 1). USGS is exploring alternative sources for certain data, such as agricultural data (animal counts, fertilizer applications rates), drainage basin delineations, and meteorological data. DNREC will make final recommendations regarding alternative data sources.

2. Prepare initial model segmentation and present to DNREC for final approval. This will necessitate getting final requested data that is the responsibility of parties other than USGS (such as complete and accurate point-source data).

3. Develop initial model input time series (precipitation, streamflow, etc.) and model parameter data files for HSPF.

4. Calibrate hydrologic portion of watershed model, following calibration and verification procedures outlined in the section on approach, above.

Data Type	Source	Provider	Comments
GIS to define hydrologic response units			
Geology	**DGS**	**DGS**	
Soils	**NRCS**	**DGS**	
Land-surface elevation (DEM)	**USGS**	**DNREC**	
Land use and land cover	**DNREC**	**DNREC**	**DE DOP, 1997**
Natural drainage network (hydrography)	**USGS**	**USGS**	**1:100,000 NHD**
Artificial drainage network (ditches)	**USGS**	**USGS**	**1:100,000 NHD**
Drainage basin delineations	USGS/DGS	USGS/DGS	Originally due October 2000
Input time-series data for hydrologic modeling			
Streamflow	USGS	USGS	March 2001
Meteorological data (precipitation, etc.)	NCDC	USGS	March 2001
Water use	USGS	USGS	March 2001
Ancillary data for hydrologic modeling			
Channel geometry, roughness, gradient	FEMA	DNREC/USGS	March 2001
Discrete-sample data for water-quality modeling			
Nutrient concentrations	DNREC	DNREC	April 2001
Sediment concentrations (total suspended solids)	DNREC	DNREC	April 2001
Sediment size distribution	DNREC	DNREC	April 2001
Field parameters (water temperature, pH, D.O.)	DNREC	DNREC	April 2001
GIS and ancillary data for water-quality modeling			
Cropland	DNREC	DNREC	April 2001
Pasture	DNREC	DNREC	April 2001
Confined-feeding operations	DGS	DGS	April 2001
Fertilizer application rates	USDA	DNREC	April 2001
Manure application rates	USDA	DNREC	April 2001
Atmospheric deposition	NADP	DNREC	April 2001
Wetlands	DNREC	DNREC	Originally due October 2000
Point sources	**DNREC**	**DNREC**	**NPDES**

Table 1. Data Requirements and Responsibilities for HSPF Implementation. [DGS, Delaware Geological Survey; NRCS, Natural Resources Conservation Service; USGS, U.S. Geological Survey; DNREC, Delaware Department of Natural Resources and Environmental Control; USEPA, U.S. Environmental Protection Agency; NCDC, National Climatic Data Center; FEMA, Federal Emergency Management Agency; DE DOP, Delaware Department of Planning]